Fermi National Accelerator Laboratory

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Standardization of CDF and DØ Reported Luminosities

J. Bantly, R. Plunkett, S. Pruss and M. Tartaglia

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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Introduction

During FNAL collider store 5094, CDF and DØ modified the computation of their reported luminosities to utilize a standardized world average inelastic cross-section. The changes made at each experiment and in the Accelerator Division are detailed below. A net decrease was expected and was observed for the reported instantaneous luminosity from each experiment. These changes affect the estimates of instantaneous and integrated luminosities reported to the Accelerator Division for the purposes of operational coordination.

Changes in CDF Reported Luminosities

The CDF Beam-beam Counters

The CDF Beam-beam counters consist of two planes of scintillation counters covering the angular range of 0.32° to 4.47° in both the proton and antiproton directions ($3.24 < |\eta| < 5.88$). Luminosity is determined by measuring the rate of upstream/downstream coincident hits inside a 30 ns gate (INTIME GATE) containing the point 20 ns after the time of beam crossing. Losses and halo are monitored by coincidences with upstream or downstream hits in a 100 ns gate (HALO gate) which contains the point 20 ns before the beam crossing. These coincidences are determined in NIM logic and read out into the CDF data stream through a Struck STR200 FASTBUS scaler. At the same time the coincidence signals are sent to MechTronics 777 ratemeters for display and control purposes, and to provide signals compatible with the ACNET control system.

CDF ACNET Luminosity Signals

The output of the BBC ratemeters described above is digitized in a standard ACNET MADC unit. Four principal ACNET devices are specified:

C: B0LUM This is the coincidence East*West inside the INTIME gate.

C: B0LUMH This is the coincidence East*West inside the INTIME gate vetoed by any hit in the HALO gate. This veto is useful to reject backgrounds at low luminosity.

C: B0LUMV This is B0LUM with the addition of a Poisson correction for multiple events in a single crossing.

C: B0LUMP This is B0LUMH with the addition of a Poisson correction for multiple events in a single crossing.

The Poisson correction is implemented using the ACNET logarithmic transform.

At luminosities above $1.0 \times 10^{31} cm^{-2} sec^{-1}$, there is evidence that hits in the HALO gate are causing an inefficiency for counting of real interactions.

CDF Reported Integrated Luminosity

Besides the ACNET devices just listed, the coincidence output of the BBC system is sent as a compatible pulse train to a totalizing scaler (ODDMOD) in the accelerator Main Control Room. The scaler also receives the luminosity coincidence gated by the CDF trigger inhibit, for a measurement of the experimental operational efficiency. The output of ODDMOD is displayed by ACNET secondary application programs which perform the Poisson multiple event correction in software. Hence care must be taken to maintain consistency of normalization among various applications.

Visible BBC cross-section for Luminosity Measurement

Using a system of small-angle chambers to augment the BBC system, the CDF collaboration has measured the total, elastic and diffractive cross-sections for proton-antiproton collisions [1] [2] [3]. These measurements yield a total inelastic cross-section of 60.3 ± 1.4 mb, and a visible BBC cross-section of 51.1 ± 1.3 mb. Previous extrapolations from lower energies [4] gave a lower value of 46.8 ± 3.2 mb for the visible BBC cross-section.

For purposes of cross-experimental comparison, it is important that consistent values of measured quantities be used. After discussion, the D0 and CDF collaboration have agreed to use the world-average inelastic proton-antiproton cross-section as an input to experiment-specific luminosity algorithms. Averaging the CDF and E710 results yields an inelastic cross-section of 58.9 ± 1.2 mb. [5].

To proceed to a visible BBC cross-section, we follow the procedure outlined by the CDF luminosity group in ref. [6], section 2. The total inelastic cross-section (average) is scaled by the ratio $\sigma(BBC)/\sigma(inel.)$ from the CDF measurement to yield a corrected visible cross-section of 49.9 mb, which differs by 2.4% from the CDF value given above.

Standardization of CDF ACNET Luminosity Signals

All the CDF signals listed above were modified to use the standardized visible cross-section of 49.9 mb at approximately 1630 on 18 August, 1994, during Store 5094. Prior to this time the devices had used a value of 46.8 mb. This corresponds to a change in reported luminosity of -6.2%.

At the same time as the cross-section was changed, changes were made in the CDF reporting of integrated luminosity. The input to the ODDMOD totalizing scaler was previously given the HALO-gate vetoed coincidences equivalent to the C:B0LUMH device; this was changed to receive the unvetoed coincidences equivalent to C:B0LUM. The ACNET secondary applications which display ODDMOD sums (pages E8 and D63) were modified to use the standardized visible BBC cross-section where necessary. Measurements at CDF show good agreement between the integrals of ACNET variables and the results of applications using ODDMOD sums as input.

Changes in DØ Reported Luminosities

DØ converted to the world average inelastic cross-sections in its reported luminosities at the same time as CDF. The switchover was coordinated with changes at CDF and in the Channel 13 display described elsewhere in this note. These DØ changes affect the devices D0LUM1 and D0LUMC which are used to generate DØ 's luminosity numbers as shown on Channel 13.

The LØ Trigger and Luminosity Detector

The DØ Detector measures both instantaneous and integrated luminosity with the LØ trigger. It consists of two scintillator arrays located just outside the central tracking chambers and in front of the end calorimeters along the Tevatron beampipe at DØ . Luminosity is obtained by measuring the rate of $\bar{p}$-p beam crossings in which both arrays are struck by particles. A complete description of the LØ trigger for the DØ Detector is available elsewhere [7].

DØ ACNET Devices D0LUM1 and D0LUMC

The D0LUM1 device measures the raw rate of crossings with collisions visible to the LØ trigger. The D0LUMC device takes the raw rate and corrects for multiple interactions. D0LUMC is the device shown on Channel 13 giving both the instantaneous and the integrated luminosities. These measurements are a simplified version of what DØ uses to obtain its own luminosity measurements. The DØ luminosity calculations are detailed elsewhere [8].

Changeover at DØ to the world average cross section

The first change to Channel 13 is a shift in the visible cross section to the LØ luminosity counters,caused by the move from the E710 published inelastic cross sections [9] to the world average of E710 and CDF [1] [2] [3] inelastic cross sections. This results in a shift of $\sigma_{\mathrm{L}\emptyset} = 42.9$mb to $\sigma_{\mathrm{L}\emptyset} = 48.2$mb. The calculation is documented elsewhere [5]. The shift is shown pictorially in the attached table. This shift appears in the denominator of the two ACNET devices D0LUM1 and D0LUMC.

<table>
<tr><th>Before:</th><th>After:</th></tr>
<tr><td>Using E710
results
⇓
$\sigma_{\mathrm{L}\emptyset}$ =42.9mb</td><td>Use CDF+E710
world average
of results
⇓
$\sigma_{\mathrm{L}\emptyset}$ =48.2mb</td></tr>
<tr><td colspan="2">↘ ↙
Effect ⇒ -12.4%</td></tr>
<tr><td colspan="2">Observed ⇒ -12%</td></tr>
</table>

Near the beginning of Store 5094, the constants in the database that form the conversions to the raw rate into the two devices were modified. This change was immediately noted when the various datalogger processes were restarted. The result showed up on Channel 13 as expected. A rough measurement indicated the expected 12% drop in the DØ instantaneous luminosity. For the DØ bunch by bunch luminosity counting and luminosity information storage, the DØ luminosity database was modified to use the new visible cross section at 1650 hours. This change alters the numbers reported weekly by DØ .

Test at DØ of SUM36A Configuration

The second change that took place was the shift from SUM20 configuration to SUM36A, which is an increase in coverage and a 14dB gain in signal that would make the LØ trigger more efficient for very low multiplicity inelastic collisions. SUM20 sums the inner 20 scintillator counters in each LØ counter array. It was used in the 1992-1993 run and in the current run. SUM36A includes 16 additional counters outside the SUM20 counters and the signal has a net amplification of 14dB. Unfortunately, the SUM36A configuration saturated the LØ discriminators badly and caused spurious signals outside the beam crossing window. The L1 Z-vertex resolution degraded more than expected, washing out halo monitoring. The SUM36A configuration remained in place for all of store 5094 to study its effects. After store 5094, the LØ trigger was returned to SUM20 operation. The saturation problem will be solved by replacing the current amplifiers with dual slope amplifiers. The dual slope will allow the LØ trigger to remain efficient for the low multiplicity interactions while preventing multiple interaction beam crossings from saturating the electronics. These will be ready for installation in fall of 1994.

Accelerator Changes to Channel 13 Monitoring

The Accelerator Division helped CDF and DØ implement the changes in luminosity normalization discussed in the previous sections. At the same time the signal used for the Channel 13 display of CDF integrated luminosity was changed back from the over corrected halo-vetoed signal C:B0LUMP to C:B0LUMV. All the console programs that transform or integrate these signals were changed at nearly the same time. The net result was about a 6% decrease in the channel 13 reported CDF instantaneous luminosity and a partially cancelling change in the Channel 13 reported CDF integrated luminosity, whose magnitude depends on the store conditions. (A measurement at CDF on 26 August, 1994, showed agreement to 0.5% between the Channel 13 weekly integrated CDF luminosity and the integral of corresponding datalogged ACNET devices.) Both the instantaneous reported luminosity and the integrated luminosity reported for DØ decreased by about 12%.

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